Workplace Exposure Standards – Interpretations of the current NZ WES for Carbon Monoxide

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ABSTRACT

Carbon monoxide (CO) is a gas found in many workplaces, particularly where vehicles with internal combustion engines are used. Exposure to carbon monoxide can cause a number of adverse health effects including cardiac arrhythmias, visual disturbances and, at high concentrations, unconsciousness and death. The New Zealand Workplace Exposure Standard (WES) for carbon monoxide has been established as 'time totals' at three different concentrations (50ppm, 100ppm and 200ppm); a departure from the familiar time weighted average concentrations used for most other exposure standards. The WES for carbon monoxide is based on the premise that by not exceeding the defined air concentrations of carbon monoxide, carboxyhaemoglobin (COHb) concentrations should be kept below the Biological Exposure Index (BEI) of 3.5% COHb. The WES are presented as discrete concentrations against which actual workplace concentrations are to be compared. In practice, difficulty arises with this when attempting to compare fluctuating concentrations against a single number WES. By examining CO exposure data from field studies the difficulty with using the present WES is illustrated and a method for assessing exposure data within the current WES is proposed.

INTRODUCTION

Exposure to carbon monoxide (CO) can result in adverse health effects. These range from cardiovascular and neurobehavioural effects in sensitive individuals exposed at low ambient concentrations to unconsciousness and death after acute exposure to high concentrations of carbon monoxide (WHO 1999) (Environment Canada 1994).

An important 'at risk' group are those who suffer adverse health effects from low level concentrations (generally below 25ppm) such as exacerbation of cardio vascular symptoms e.g. angina. Also of occupational significance are the probable increased risks for some of those with existing cardio vascular or pulmonary disease, those with anaemias which may affect the oxygen carrying capacity of the blood and the developing foetus.

As CO concentrations increase, additional symptoms are seen even in fit healthy individuals due to increasing formation of carboxyhaemoglobin (COHb) which reduces the oxygen carrying capabilities of the red blood cell. Symptoms may include, headache, nausea, irritability, difficulty in concentrating, dizziness, fatigue, confusion, rapid breathing and heartbeat, seizures, respiratory failure, coma and death.

The normal level of carboxyhaemoglobin is <1%. Smokers may typically have levels of 5 - 8% whereas an inner-city jogger may have levels of up to 12%. Those exhibiting symptoms resulting from higher exposures to CO generally exhibit COHb levels upwards of 20% and levels of greater than 65% are usually considered fatal without therapy.

It is against this background that the New Zealand Workplace Exposure Standards (WES) for carbon monoxide are set. The WES are set out in a document (Department of Labour 2002) Workplace Exposure Standards – Effective from 2002 with the stated aim of controlling workplace exposures to CO so that COHb levels are maintained below 3.5%.

The guidance from the Department of Labour is as follows:

If the average CO concentration over an 8 hour period does not exceed 25ppm a COHb levels of less than 3.5% will likely be achieved.
In order to maintain COHb levels below 3.5% where there are brief periods of high exposure the sum of the exposure periods during the day should not (in total) exceed the periods as shown in Table 1.

Table 1. Short Term Excursions for CO exposure

Concentration ppm	Exposure Period minutes
50	60
100	30
200	15
400	Should not be exceeded at any time during the working day

The difficulty in interpreting the short term excursion WES arises when, as is invariably the case in workplace exposures, concentrations are measured between the figures quoted; for example, how is a concentration of 150ppm interpreted within the context of the WES?

AIMS

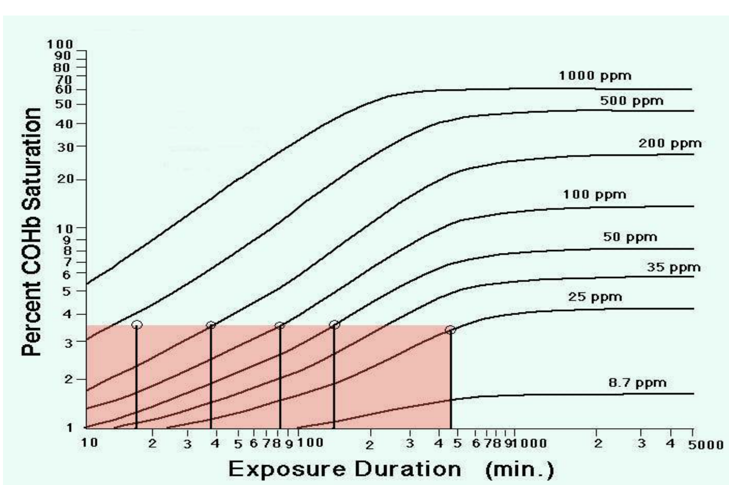
The aim of this paper is to describe a method by which fluctuating concentrations of CO, especially those between 50ppm and 400ppm, can be interpreted against the WES.

METHODS

Data Collection
Workplace exposures were measured by a battery powered RAE Systems QRAE datalogging CO meter. The meter was worn by an employee throughout a workshift during which an LPG powered vehicle was used in a warehouse environment. The QRAE is fitted with an electrochemical sensor for the measurement of CO concentrations between 0 and 500ppm with a resolution of 1ppm. The datalog was set to average and log at 1 minute intervals throughout the shift.

Estimation of carboxyhaemoglobin
Well proven models for estimating COHb levels have been in use for many years. The most frequently used model is that of Coburn Forster and Kane (Coburn et.al. 1965). A similar model by Peterson and Stewart (Peterson and Stewart 1970) gives comparable results. The Coburn Forster and Kane (CFK) model was used to interpret the data within the context of the WES and the CFK nomogram is shown in Fig 1.

Fig 1. Percentage COHb for various exposure durations and ambient CO concentrations



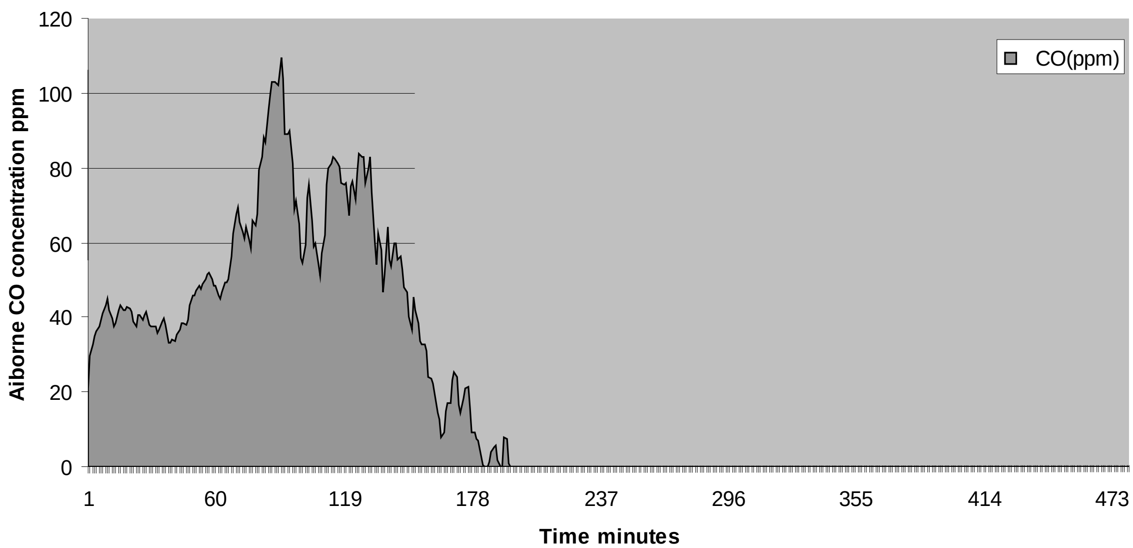
The shaded area in Fig 1. delineates the 3.5% COHb intersections with the various ppm curves up to 480 minutes (8 hours) of exposure.

RESULTS

Exposure Data

Two sets of exposure data were chosen to exemplify the issues facing those having to interpret exposure data within the context if the WES. Data Set A (Fig 2.) contained no exposure concentrations above 299 ppm and a low average concentration in the less than 25ppm Concentration Band. Data set B (not shown) contained two minutes where concentrations exceeded 199 ppm and a significantly higher average concentration for the less than 25 ppm Concentration Band. Additionally Data Set A had a lower 8 hour average CO concentration (19 ppm) than Data Set B (39 ppm).

Fig 2.Airborne CO concentrations Data Set A



Both data sets showed typical fluctuating exposure concentrations found in many workplaces.
The data was further analysed by determining the number of minutes at nominal Concentration Bands. The Bands were set by using the WES concentrations (Table 1) as a guide. The average concentration for each Band was also calculated. Additionally, the 8 hour average exposure was also determined from the data. Table 2 shows the results of the analysis.

Table 2. Short Term Excursions for CO exposure Data sets A & B

Nominal CO Concentration Band	>400 ppm		200-399 ppm		100-199 ppm		50-99 ppm		25-49 ppm		<25 ppm	
Data Set	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Number of minutes in Band	0	0	0	2	6	61	78	73	73	52	323	291
Average CO concentration	-	-	-	215	104	123	69	72	40	34	1	13
Calculated COHb %	-	-	-	<1	1	3.3	2.9	2.8	3	1.6	<1	1.8
8 hour average CO concentration	Set A= 19 ppm						Set B= 39 ppm					
Calculated COHb % (8hr)	Set A= 2.5%						Set B= 5.0%					

By using the CFK nomogram (Fig 1.) the percentage COHb was estimated for the average CO concentration in each of the Concentration Bands and the 8 hour average CO concentration.
The data shows that Data Set A exceeded the WES in the 50-90ppm range by 18 minutes but had a calculated COHb of 2.9%.
Data Set B exceeded the WES for the 8 hour average concentration by 14ppm with an calculated COHb of 5%.

DISCUSSION

With exposure concentrations that constantly fluctuate over a given time period, an averaging system is usually employed to take account of the fluctuations. Common practice over many decades has been to use 8 hour and 15 minute averaging periods. Pre 2001 the NZ WES for carbon monoxide was set at 25 ppm averaged over an 8 hour period. Recognition of the effects that short term exposures have on raising COHb above 3.5% and the increased risk this carried for certain people in the working population resulted in the time based WES being established and used from 2001 onwards.

As yet there has been no published guidance as to how to include and interpret data that falls either side of the discrete concentrations currently set for the short term WES.

The results demonstrate that with datalogging equipment it is possible to collect and assign data to Concentration Bands which then allows averaging techniques to be used for both the short duration exposure and full shift period exposures. The CFK nomogram can then be used to determine whether the exposures are likely to have resulted in an elevation of COHb over the 3.5% threshold.

It is also of note that commonly used measurement techniques such as direct reading colorimetric tubes lack the time sensitivity required to assess fluctuating concentrations. Electrochemical sensors and datalogging equipment overcome such limitations and the equipment is readily available and easy to use, albeit with some guidance required on its operation and limitations. It is the lack of guidance on interpretation of the data that limits the usefulness of the current NZ WES for carbon monoxide.

CONCLUSIONS

The current Workplace Exposure Standards for carbon monoxide are established against a background of sound occupational heath and occupational hygiene science. However the WES, as currently set out, makes no reference to an agreed method by which fluctuating exposures can be assessed.

The Workplace Exposure Standards for carbon monoxide should be reassessed with a view to publishing detailed guidance on workplace measurement and interpretation of the resulting data. The Concentration Band method outlined above should be considered as forming a basis for such guidance.

REFERENCES

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